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(54) Low noise and wide power range laser source

Laserquelle mit grossem Leistungsbereich und mit niedrigem Rauschpegel

Source laser à large bande de puissance et à bruit faible

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to laser sources and further to equipments for measuring optical components.

[0002] In optical communication networks, information is generally transmitted by optical fibers from a stimulus, e.g. a laser diode, to an optical receiver, e.g. a photo diode. These may not only be point-to-point links but may also provide a complex network structure which generates the need for optical components for data routing, adding, dropping and switching.

[0003] To increase the transmission capacity, several communication channels are normally used simultaneously. In principle, this can be realized by separating the channels by providing time multiplexing or centering channels at different wavelengths. The latter principle is also known as Wavelength-Division-Multiplexing (WDM) and is becoming increasingly important. A state of the art WDM system has about 20 channels separated by 0.8nm in a wavelength range of around 1550nm. First research work is already done to increase the amount of channels by reducing the channel spacing down to 0.2nm and therefore increase the transmission capacity by about four times.

[0004] One of the problems by using WDM is the interference (cross talk) of the communication channels. To avoid interference, the used optical components need to exhibit a high wavelength dependent transmission characteristics, that is, e.g., a WDM cross-connect switch with a transmission dynamic of up to 30dB over tenths of a nanometer. A known complex and expensive measurement setup for characterizing this kind of optical components is based on a tunable laser source, a wavelength meter, a tracking filter and an optical power meter (cf., e.g., in "Fiber optic test and measurement" by Dennis Derickson, ISBN 0-13-53480-5, page 358 ff.).

[0005] In general, the signal to total noise ratio of a laser source (e.g. a tunable laser source as depicted in the above mentioned book by Dennis Derickson on page 360) limits its applications where high transmission dynamics characteristics have to be measured, e. g., in case of a notch-filter with a high signal suppression, such as a fiber grating, where the back noise (SSE, ASE) of the laser source determines the measured suppression of a signal positioned at a center wavelength of the filter (cf. Fig. 6).

[0006] A solution to improve the signal-to-noise ratio of a laser system is to provide a filter in combination with a broadband receiver or an optical spectrum analyzer. To ensure also the wavelength accuracy of the measurement, which is very important in WDM systems with narrow channel spacing, also known as Dense Wavelength Division Multiplexing (DWDM), an external wavelength meter has to be used. For all these setups an additional controller plus software is needed for synchronizing and data capturing.

[0007] JP-A-06 140717, Lewis L. L. in "Low noise laser for optically pumped cesium standards" (proceedings of the annual frequency control symposium, Denver, May 31 - June 2, 1989, no. Symp. 43, 31 May 1989, Institute of electrical and electronics engineers, pages 151-157, XP000089353), and Boshier M. G. et al. in "External-Cavity frequency stabilization of visible and infrared semiconductor lasers for high resolution spectroscopy" (Optics communications, vol. 85, no. 4, 15. Sept. 1991, pages 355-359, XP000226852) disclose laser systems with a beam splitter provided in the external cavity. Fig. 1 shows in principle a laser source 5 according to those prior art documents.

[0008] A laser gain medium or amplifier 10 provides a first facet 20 which is low reflective and a second facet 30 which is high reflective. The first facet 20 emits a laser beam 50 into an external cavity of the laser source 5. A collimating lens 60 collimates the laser beam 50 to a beam splitter 65 splitting the laser beam 50 into a part 50' and a part 67. The part 50' of the laser beam 50 is directed to an optical grating 70 as a wavelength dependent mirror. The optical grating 70 diffracts the incident beam 50' and a wavelength separated beam 50" is directed back towards the beam splitter 65. The angle of the optical grating 70 with respect to the beam 50" depends on the wavelength to be selected. The optical grating 70 together with the facet 30 of the semiconductor amplifier 10 define the optical resonator of the laser source 5. The beam splitter 65 splits up the returning beam 50" into a beam 50"' towards the gain medium 10 and a beam 80. The laser system 5 provides as output signals the laser beams 67 and 80, coupled out respectively from the beam splitter 65. The output beam 80 can be coupled into a fiber 90, e.g., by means of an optical lens 100.

[0009] Jeffrey Bernstein et al in "Oscillator design improves dye-laser performance" (Laser Focus World, Sept. 1995, pages 117 ff.) discloses that the laser beam 80, which is substantially coupled out directly after wavelength selection by the optical grating 70 provides an improved lower signal-to-noise ratio output with respect to the output beam 67.

[0010] In modern laser applications, in particular for measuring purposes e.g. for measuring modern optical components for DWDM, it becomes increasingly important to provide flexible laser systems offering a wide range of laser signals from high power signals to low noise signals. Although the output 67, coupled out directly the gain medium 10 in the laser system 5 of Fig. 1, provides a possibility for a higher power output with regard to the output 80, the output 67 finds a power limitation in the beam splitter 65. Since the beam splitter 65 couples out as well the beam 80 as the beam 67 necessarily with the same coupling-out-ratio, or in other words, since the beam splitter 65 couples out the power of beam 67 or 80, a certain tradeoff between the possible power to be coupled out and the resonator condi-

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. Features that are or can be built up substantially equally or similarly are referred to with the same reference sign.

Fig. 1	shows a state of the art laser source,
Fig. 2	shows a laser source according to the invention,
Figs. 3 and 4	show representative spectra of output beams of the laser source of Fig. 2,
Fig. 5	depicts a preferred application of the laser source according to the invention is in an arrangement for measuring optical devices or components, and
Fig. 6	shows a measurement plot for an example of a notch filter as DUT in the arrangement of Fig. 5.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Fig. 2 depicts a laser source 200 according to the invention, which can comprise the same features as the laser source 5 of Fig. 1. However, as a first improvement with respect to the laser source 5, the second facet 30 of the laser gain medium 10 in the laser source 200 is provided to be partly (and preferably high) reflective, so that the second facet 30 emits an output beam 210 outside of the external cavity of the laser source 200. The output beam 210 is coupled into a second optical fiber 220, such as a single mode fiber, preferably by applying a collimating lens 230, an optical isolator 240 for avoiding disturbances of the amplifier 10 from any signal outside of the laser source 200, and a further collimating lens 250. Other means as known in the art for coupling out the output beam 210 might be applied accordingly, dependent on the specific application.

[0022] Extracting the output laser beam 210 directly behind the amplifier 10 allows generating a laser signal with a significantly higher signal power, in particular with respect to the output beam 80 and the beam 67. However, it is to be understood, that passing the gain medium 10 on one hand increases the power of the beam, on the other hand also decreases the signal-to-noise ratio due to additional source spontaneous emission (SSE). Although the signal-to-noise ratio of the high power output laser beam 210 is lower compared with output beam 80, it is still exhibits an improved signal-to-noise ratio over the beam 67.

[0023] In a preferred embodiment, only the beams 80 and 210 will be provided as output beams of the laser source 200, while the beam 67 remains unused and/or is applied for monitoring the laser beam 50.

[0024] The beam splitter 65 is preferably optimized for extracting optical power for the output beam 80 without significantly reducing the optical feedback of the external cavity. In a preferred embodiment, the reflectivity of the beam splitter 65 is selected to be approximately 1/10, i.e. 1/10 of the incident beam is reflected either as beam 67 or 80. The beam splitter 65 can be embodied by a simple glass plate, whereby one side has a partly reflecting coating and the other side has an anti-reflective coating. To avoid, in addition, internal interference effects the two sides (faces) are preferably tilted regarding to each other.

[0025] Fig. 3 shows a spectrum of a representative output beam 210, wherein the x-axis depicts the wavelengths and the y-axis depicts the power density of the output beam 30. The spectrum exhibits a signal peak 300 at a laser wavelength λ_L and a background noise 310 provided by the called Source Spontaneous Emission (SSE) or Amplified Spontaneous Emission (ASE). In most applications of semiconductor lasers, the signal peak 300 exhibits a signal to noise ratio of about 20 dB as depicted in Fig. 3a.

[0026] As another improvement over the laser source 5 in Fig. 1, the output beam 80 is preferably coupled into the fiber 90 via a fixture (not shown in Fig. 2) to align the fiber 90 to the optical lens 100 in dependence of the output beam 80.and an optical isolator 260 for avoiding disturbances of the amplifier 10 from any signal outside of the laser source 200

[0027] As a further improvement over the laser source 5 of Fig. 1, either in addition to the provision of the output beam 210 or independent thereof, the laser source 200 of Fig. 2 further provides a mirror 270, which can be e. g. a plane or curved (preferably concave or convex) mirror or a dihedral element. The mirror 270 in conjunction with the optical grating 70 provides an improved wavelength dependent mirror 280 over the application of the optical grating 70 as depicted in Fig. 1.

[0028] The mirror 270 is arranged in a way that the part of the beam 50' reaching the grating 70 is diffracted by the grating 70 to the mirror 270. The mirror 270 reflects back the diffracted and thus wavelength filtered beam to the grating 70, which again diffracts the incoming beam from the mirror 270 towards the beam splitter 65. The twice-diffracted beam provides the wavelength separated laser beam 50".

[0029] Preferably, the mirror 270 is arranged in a Littman-configuration allowing a mode-hop free wavelength tuning of the laser source 200. In the Littman-configuration, as known in the art, planes through the grating 70, the mirror 270, and the facet 30 substantially intersect in a point 290.

(65) is optimized for extracting optical power for the first output beam (80) without significantly reducing the feedback beam.

4. The laser source (200) according to any one of the claims 1-3, characterized in that the beam splitter (65) is a glass plate, preferably comprising one side with a partly reflecting coating and another side with an anti-reflective coating, whereby the two sides are preferably tilted regarding to each other.

5. The laser source (200) according to any one of the claims 1-4, characterized in that the first output beam (80) and/or the second output beam (210) are/is coupled out by means of an optical lens (100) and a fixture to align the optical fiber (90) to the optical lens (100) in dependence of the output beam (80).

6. The laser source (200) of claim 5, characterized in that the first output beam (80) and/or the second output beam (210) are/is coupled out by means of an optical isolator (260) for avoiding disturbances of the laser gain medium (10) from a signal outside of the laser source (200).

7. An apparatus (500) for measuring an optical device (505) comprising:

   the laser source (200) according to any one of the claims 1-6 coupled to and controlled by a wavemeter (503), and

   one or more power meters (510a,...,510z) coupled to the optical device (505) which receives an output signal from the laser source (200).

8. The apparatus (500) of claim 7, further comprising a main controller unit (515) for data capturing and analyzing which is coupled to the laser source (200), the wavemeter (503), and the one or more power meters (510a...510z) preferably by a data bus (512).

9. The apparatus (500) of claim 7 or 8, further comprising a triggering system for simultaneously reading the wavelength of the laser source (200) and power values measured by the one or more power meters (510a...510z).

Patentansprüche

1. Laserquelle (200) mit einem optischen Resonator, die beinhaltet:

   ein Laserverstärkungsmedium (10) mit einer ersten Fläche (20), die schwach reflektierend ist, um einen Laserstrahl (50) innerhalb des optischen Resonators zu emittieren,

   einen wellenlängenabhängigen Spiegel (70) zum Empfangen des Laserstrahls (50) oder Anteilen (50') desselben und Rückreflektieren eines wellenlängenseparierten Laserstrahls (50") und

   einen Strahlteiler (65) zum Teilen des wellenlängenseparierten Laserstrahls (50") in einen Rückkopplungsstrahl (50'''), der auf das Laserverstärkungsmedium (10) gerichtet wird, und einen ersten Ausgangsstrahl (80), der aus dem optischen Resonator der Laserquelle (200) in eine erste optische Faser (90) auszukoppeln ist,

   dadurch gekennzeichnet, dass
   das Laserverstärkungsmedium (10) eine zweite Fläche (30) beinhaltet, die teilweise reflektierend ist, so dass die zweite Fläche (30) einen zweiten Ausgangsstrahl (210) der Laserquelle (200) emittiert, der in eine zweite optische Faser (220) eingekoppelt wird.

2. Laserquelle (200) nach Anspruch 1, dadurch gekennzeichnet, dass sie des Weiteren einen Spiegel (270) beinhaltet, der derart angeordnet ist, dass ein von dem wellenlängenabhängigen Spiegel (70) gebeugter Strahl rückreflektiert und erneut von dem wellenlängenabhängigen Spiegel (70) gebeugt wird, so dass der zweimal gebeugte Strahl den wellenlängenseparierten Laserstrahl (50") bereitstellt, wobei der Spiegel (270) vorzugsweise in einer Littman-Konfiguration (290) angeordnet ist.

3. Laserquelle (200) nach irgendeinem der Ansprüche 1 bis 2, dadurch gekennzeichnet, dass der Strahlteiler (65) dafür optimiert ist, optische Leistung für den ersten Ausgangsstrahl (80) ohne signifikante Reduzierung des Rückkopplungsstrahls zu extrahieren.

4. Laserquelle (200) nach irgendeinem der Ansprüche 1 bis 3, dadurch gekennzeichnet, dass der Strahlteiler (65) eine Glasplatte ist, die vorzugsweise eine Seite mit einer teilweise reflektierenden Beschichtung und eine andere Seite mit einer Antireflexbeschichtung aufweist, wobei die zwei Seiten vorzugsweise zueinander geneigt sind.

5. Laserquelle (200) nach irgendeinem der Ansprüche 1 bis 4, dadurch gekennzeichnet, dass der erste Ausgangsstrahl (80) und/oder der zweite Ausgangsstrahl (210) mittels einer optischen Linse (100) sowie einem Fixierungselement zur Justierung der optischen Faser (90) bezüglich der opti-

schen Linse (100) in Abhängigkeit von dem Ausgangsstrahl (80) ausgekoppelt werden/wird.

6. Laserquelle (200) nach Anspruch 5, dadurch gekennzeichnet, dass der erste Ausgangsstrahl (80) und/oder der zweite Ausgangsstrahl (210) mittels eines optischen Isolators (260) zur Vermeidung von Störungen des Laserverstärkungsmediums (10) durch ein Signal außerhalb der Laserquelle (200) ausgekoppelt werden/wird.

7. Vorrichtung (500) zum Vermessen einer optischen Vorrichtung (505) mit:

   der Laserquelle (200) nach irgendeinem der Ansprüche 1 bis 6, die an einen Wellenlängenmesser (503) gekoppelt ist und durch diesen gesteuert wird, und

   einem oder mehreren Leistungsmessern (510a, ..., 510z), die mit der optischen Vorrichtung (505) gekoppelt sind, die ein Ausgangssignal von der Laserquelle (200) empfängt.

8. Vorrichtung (500) nach Anspruch 7, die des Weiteren eine Hauptsteuereinheit (515) zur Datenerfassung und -analysierung beinhaltet, die mit der Laserquelle (200), dem Wellenlängenmesser (503) und dem einen oder den mehreren Leistungsmessern (510a, ... 510z) vorzugsweise durch einen Datenbus (512) gekoppelt ist.

9. Vorrichtung (500) nach Anspruch 7 oder 8, die des Weiteren ein Triggersystem zum gleichzeitigen Lesen der Wellenlänge der Laserquelle (200) und von Leistungswerten beinhaltet, die durch den einen oder die mehreren Leistungsmesser (510a, ..., 510z) gemessen werden.

Revendications

1. Une source laser (200) à résonateur optique, comprenant:

   un milieu (10) de gain laser qui inclut une première facette (20) qui est faiblement réfléchissante pour émettre un faisceau laser (50) à l'intérieur du résonateur optique,
   un miroir (70) dépendant de la longueur d'onde pour recevoir le faisceau laser (50), ou des parties (50') de celui-ci, et réfléchir en retour un faisceau laser (50") à longueurs d'ondes séparées, et
   un diviseur (65) de faisceau pour diviser le faisceau laser (50") à longueurs d'ondes séparées en un faisceau de rétroaction (50"') dirigé vers le milieu (10) de gain laser et un premier faisceau de sortie (80) à coupler hors du résonateur optique de la source laser (200) vers une première fibre optique (90);

   caractérisée en ce que
   le milieu (10) de gain laser comprend une deuxième facette (30) qui est partiellement réfléchissante de sorte que la deuxième facette (30) émet un deuxième faisceau de sortie (210) de la source laser (200) qui est couplé vers une deuxième fibre optique (220).

2. La source laser (200) selon la revendication 1, caractérisée en ce qu'elle comprend en outre un miroir (270) agencé d'une manière telle qu'un faisceau diffracté par le miroir (70) qui dépend de la longueur d'onde est réfléchi en retour et est de nouveau diffracté par le miroir (70) qui dépend de la longueur d'onde, de sorte que le faisceau diffracté deux fois constitue le faisceau laser (50") à longueurs d'ondes séparées, le miroir (270) étant de préférence agencé selon une configuration de Littman (290).

3. Le faisceau laser (200) selon la revendication 1 ou 2, caractérisé en ce que le diviseur (65) de faisceau est optimisé de manière à extraire une puissance optique pour le premier faisceau de sortie (80) sans réduire de façon significative le faisceau de rétroaction.

4. La source laser (200) selon l'une quelconque des revendications 1 à 3, caractérisée en ce que le diviseur (65) de faisceau est une plaque de verre, qui comprend de préférence une première face à revêtement partiellement réfléchissant et une autre face à revêtement anti-réfléchissant, les deux faces étant de préférence inclinées l'une par rapport à l'autre.

5. Le faisceau laser (200) selon l'une quelconque des revendications 1 à 4, caractérisé en ce que le premier faisceau de sortie (80) et/ou le deuxième faisceau de sortie (210) est ou sont couplés vers l'extérieur au moyen d'une lentille optique (100) et d'une monture pour aligner la fibre optique (90) avec la lentille optique (100) en fonction du faisceau de sortie (80).

6. La source laser (200) selon la revendication 5, caractérisée en ce que le premier faisceau de sortie (80) et/ou le deuxième faisceau de sortie (210) et ou sont couplés au moyen d'un isolateur optique (260) pour éviter de perturber le milieu (10) de gain laser par un signal extérieur à la source laser (200).

7. Un appareil (500) de mesure d'un dispositif optique (505) comprenant:

la source laser (200) conforme à l'une quelconque des revendications 1 à 6, couplée à un ondemètre (503) et commandée par celui-ci, et un ou plusieurs instruments de mesure de puissance (510a, ..., 510z) couplés au dispositif optique (505) qui reçoit un signal de sortie de la source laser (200).

8. L'appareil (500) selon la revendication 7, qui comprend en outre une unité principale (515) de dispositif de commande qui est destinée à capter et analyser des données et est couplée à la source laser (200), à l'ondemètre (503) et à l'instrument de mesure (510a,..., 510z) de puissance ou à lumineuse d'entre eux, de préférence par un bus (512) de données.

9. L'appareil (500) selon la revendication 7 ou 8, qui comprend en outre un système de déclenchement pour lire simultanément la longueur d'onde de la source laser (200) et des valeurs de puissance mesurées par un ou plusieurs instruments de mesure (510a,..., 510z) de puissance.

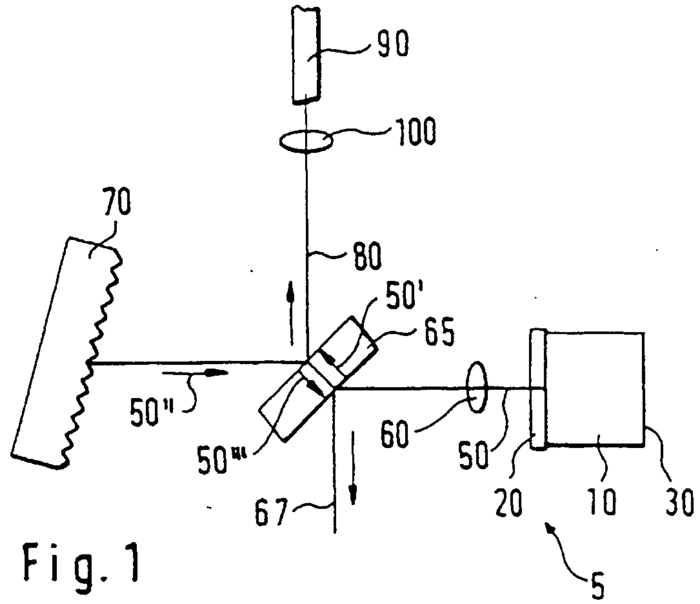
90
100
70
80
50'
65
50''
60
50'''
50
20
10
30
67
5

Fig. 1

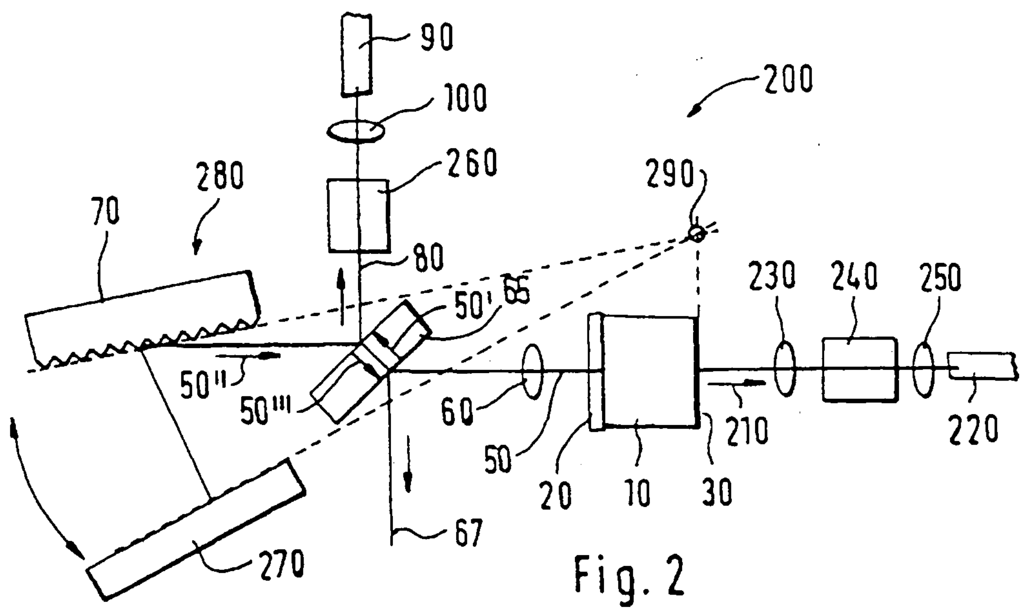
90
100
200
260
280
70
290
80
230
240
250
50'
65
50''
50'''
60
210
220
50
20
10
30
67
270

Fig. 2

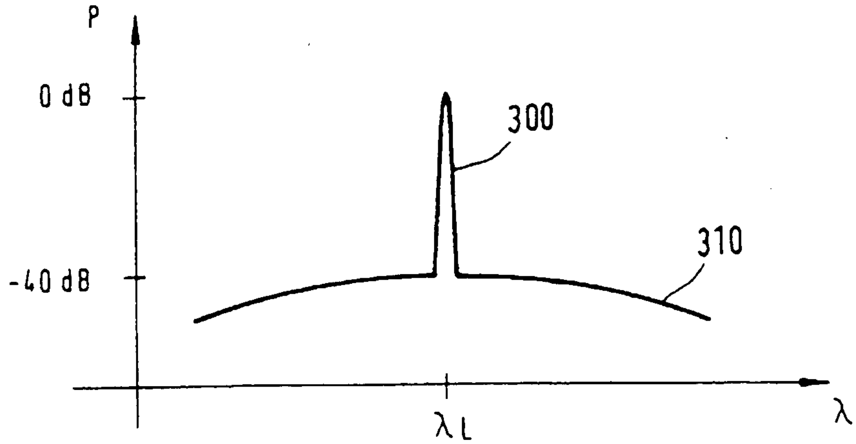

Fig. 3

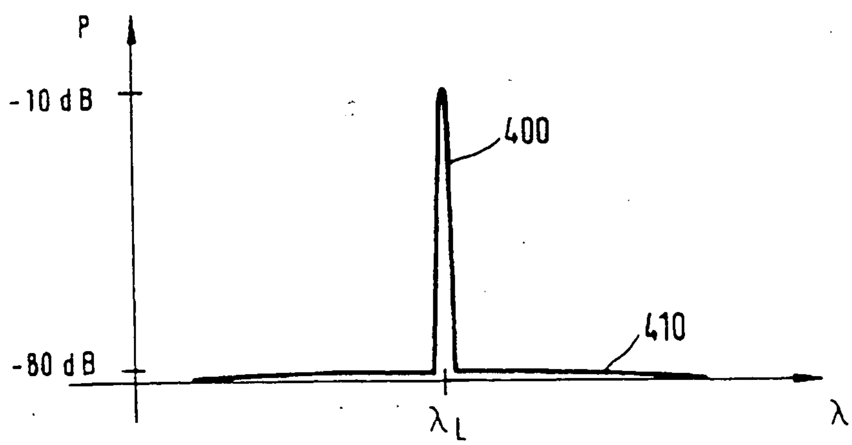

Fig.4

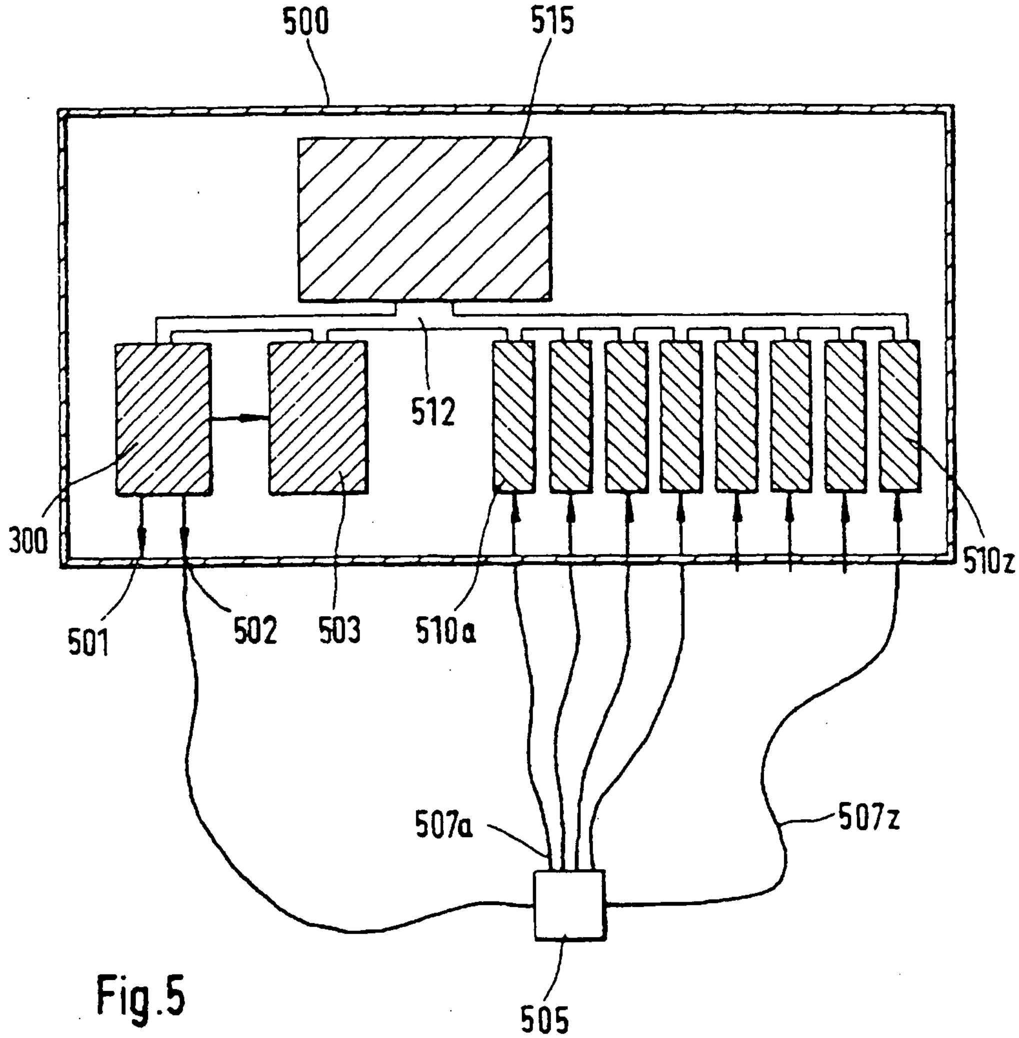

Fig.5

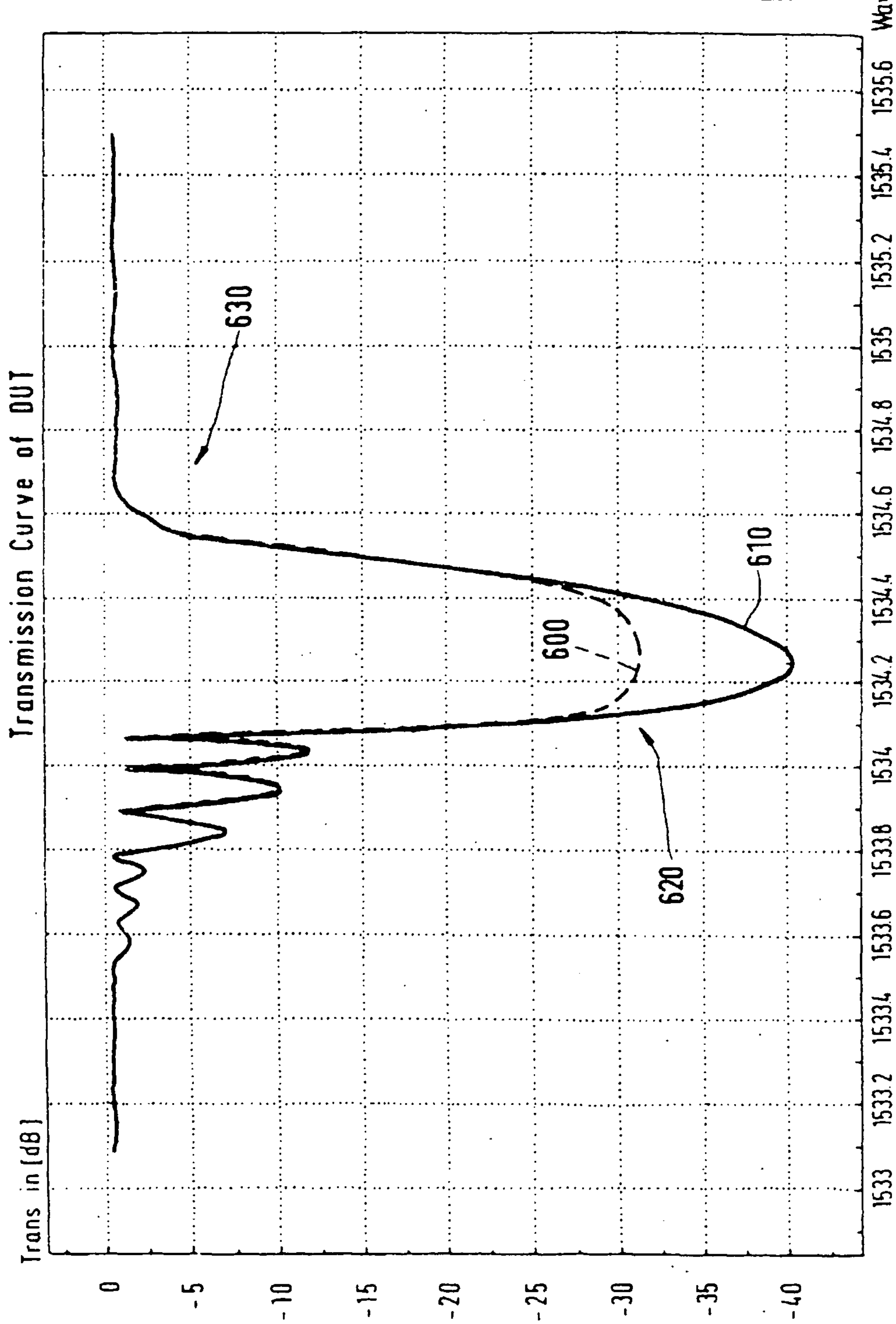
Transmission Curve of DUT
Trans in [dB]
0
-5
-10
-15
-20
-25
-30
-35
-40
1533
1533.2
1533.4
1533.6
1533.8
1534
1534.2
1534.4
1534.6
1534.8
1535
1535.2
1535.4
1535.6
Wave in mm
630
610
600
620

Fig.6